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Single Charged MSSM Higgs-boson production at a Linear Collider [*]

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Abstract

In the Minimal Supersymmetric Standard Model we present the calculation of the single charged Higgs-boson production in the γW- or ZW-fusion and the charged Higgs strahlung channel, $e^+e^- \to e\nu_e\, H^\pm$. The set of all $O(\alpha)$ corrections arising from loops of Standard Model fermions and scalar fermions are taken into account. Contrary to the case of single neutral heavy CP-even Higgs-boson production, for the charged Higgs boson we find for all the parameter space of the typical benchmark scenarios a cross section smaller than ~ 0.01 fb for $\sqrt{s}/2 \lesssim M_{H^\pm}$.

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SINGLE CHARGED MSSM HIGGS-BOSON PRODUCTION AT A LINEAR COLLIDER*

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1. Introduction

Disentangling the mechanism that controls electroweak symmetry breaking is one of the main tasks of the current and next generation of colliders. The prime candidates are the Higgs mechanism within the Standard Model (SM) or within the Minimal Supersymmetric Standard Model (MSSM). Contrary

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to the SM, two Higgs doublets are required in the MSSM, resulting in five physical Higgs bosons: the light and heavy CP-even h and H, the CP-odd A, and the charged Higgs bosons $H^{\pm}$. The Higgs sector of the MSSM can be expressed at lowest order in terms of M_Z, M_A, and $\tan\beta = v_2/v_1$, the ratio of the two vacuum expectation values.

Pair production of the heavy MSSM Higgs bosons at a Linear Collider (LC) is limited by kinematics to $M_H \approx M_A \approx M_{H^\pm} \lesssim \sqrt{s}/2$. Thus single Higgs-boson production (including electroweak loop effects) has recently drawn considerable interest in the literature [1,2]. It has been found that the processes $e^+e^- \to \bar{\nu}\nu\, H$ could allow for the discovery of the H significantly beyond the kinematic limit once the dominant loop corrections are taken into account [1]. On the other hand, $e^+e^- \to \nu_e\bar{\nu}_e A$, $e^+e^- \to Z^* \to H\{Z, A\}$, $e^+e^- \to W^\pm H^\mp$, and $e^+e^- \to t\bar{b}H^-$ [2] only possess a small potential to produce the heavy MSSM Higgs bosons with $M_H \approx M_A \approx M_{H^\pm} > \sqrt{s}/2$.

Here we present results for the channel $e^+e^- \to e\nu_e\, H^\pm$ in the MSSM. Since there is no tree-level $\{\gamma, Z\}W^\pm H^\mp$ coupling, the single charged-Higgs production starts at the one-loop level. We take into account the leading corrections arising from the full set of SM fermion and sfermion loops. In the case of $e^+e^- \to \bar{\nu}\nu\, H$ this type of diagrams constitutes the leading contribution affecting the decoupling behavior of the H [1].

2. Calculation

The one-loop SM fermion and sfermion diagrams for the process $e^+e^- \to e\nu_e\, H^\pm$ are generically depicted in Fig. 1 (s-channel diagrams and self-

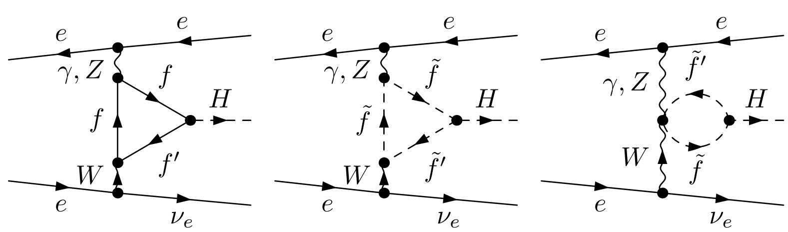


Figure 1. Generic t-channel diagrams for the process $e^+e^- \to e\nu_e\, H^\pm$.

energy corrections have been omitted). The contributions involve all corrections from SM fermion and sfermion loops (which give contributions only to self-energies and vertices). Contributions $\propto m_e/M_W$ were neglected. Furthermore, counterterm contributions are needed for the $W^\pm H^\mp$ self-

energy corrections, see Ref. [3]. In order to generate the counterterms, it is sufficient to introduce the field renormalization constant for the $H^\pm - W^\pm$ mixing, δZ_{HW}. This leads to the Feynman rules for the counterterms,

$$\Gamma_{\rm CT}[H^\mp W^\pm(k^\mu)] = i\frac{k^\mu}{M_W} M_W^2\, \delta Z_{HW}\ , \tag{1}$$

$$\Gamma_{\rm CT}[\gamma_\mu W^\pm_\nu H^\mp] = -ieM_W g_{\mu\nu}\, \delta Z_{HW}\ , \tag{2}$$

$$\Gamma_{\rm CT}[Z_\mu W^\pm_\nu H^\mp] = ieM_W \frac{s_w}{c_w} g_{\mu\nu}\, \delta Z_{HW}\ . \tag{3}$$

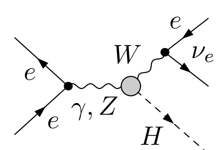
In the on-shell scheme δZ_{HW} is given by

$$\delta Z_{HW} = 1/M_W^2\ \mathrm{Re}\,\Sigma_{HW}(M_{H^\pm}^2)\ . \tag{4}$$

The Feynman diagrams were generated and evaluated with the packages *FeynArts*, *FormCalc*, and *LoopTools* [4–6].

3. Results

The results for H^+ and H^- production are the same if CP is not violated (which we assume throughout the paper). In Fig. 2 we show the typical size of the production cross section for $e^+e^- \to e^+\nu_e\, H^-$ for unpolarized external particles. The parameters are chosen according to the four benchmark scenarios described in Ref. [7], with $M_A = 250$ GeV and $\tan\beta = 2$ and 10 (with $M_{H^\pm} \approx 262$ GeV). Concerning the discovery of the charged Higgs boson at a LC, the number of expected events is obtained from a twice as large cross section, due to the production of both, H^+ and H^-. In Fig. 2 the cross section for $e^+e^- \to e^+\nu_e\, H^-$ is shown as a function of $\sqrt{s}$. The rise of the cross section at $\sqrt{s} \approx M_{H^\pm} + M_W$ is due to the W propagator in the type of diagram on the right becoming resonant. The resonance was treated with a fixed width.



The variation within the four benchmark scenarios is small. For $\tan\beta = 10$ the charged-Higgs production cross section stays at a negligible level. Even for $\tan\beta = 2$ it stays below 0.01 fb for $2\,M_{H^\pm} \approx \sqrt{s} \lesssim 500$ GeV. Using polarized e^+ and e^- beams, the cross section could be enhanced by about a factor of 2.

In summary, the single charged-Higgs production, $e^+e^- \to e\nu_e\, H^\pm$, is most relevant for small values of $\tan\beta$, which are still marginally allowed from LEP Higgs searches if the experimental error on the top mass and theoretical uncertainties are taken into account [8, 9]. This process could possibly increase the potential of a LC for the detection of the heavy MSSM

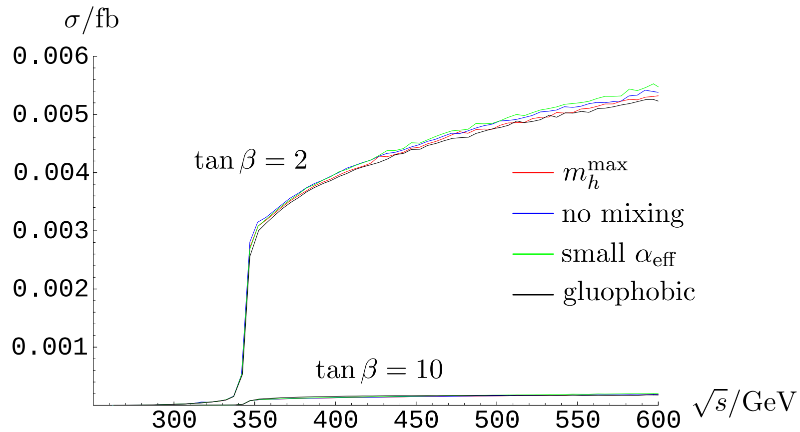


Figure 2. The $e^+e^- \to e^+\nu_e\, H^-$ production cross section as a function of $\sqrt{s}$.

Higgs-boson spectrum only for parameters beyond the typical benchmark scenarios.

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